Lepton-Nucleus Cross Section Measurements for DUNE with the LDMX Detector

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We point out that the LDMX (Light Dark Matter eXperiment) detector design, conceived to search for sub-GeV dark matter, will also have very advantageous characteristics to pursue electron-nucleus scattering measurements of direct relevance to the neutrino program at DUNE and elsewhere. These characteristics include a 4-GeV electron beam, a precision tracker, electromagnetic and hadronic calorimeters with near 2π azimuthal acceptance from the forward beam axis out to ~40° angle, and low reconstruction energy threshold. LDMX thus could provide (semi)exclusive cross-section measurements at DUNE-like kinematics, with detailed information about final-state electrons, pions, protons, and neutrons.

Modeling neutrino-nucleus scattering is difficult

- Modeling neutrino-nucleus interactions is crucial for long-baseline oscillation experiments
- Extensive data validation against generators is needed
- Electron-nucleus data is a useful validation dataset

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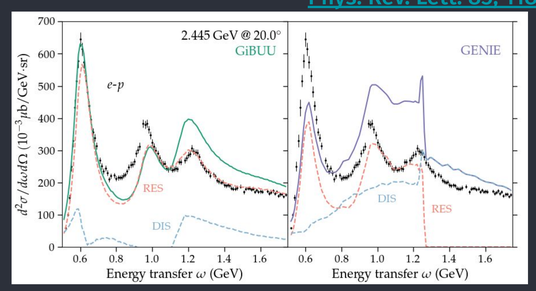
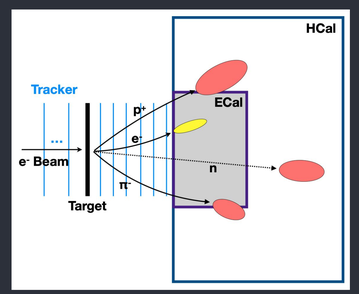
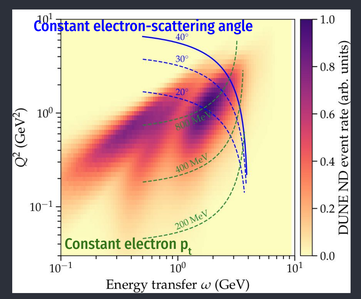


- This inclusive cross sections show serious discrepancy between data and neutrino generator predictions

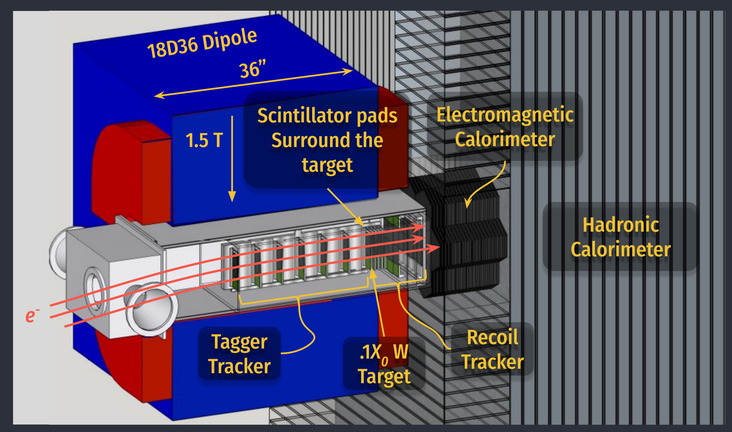
LDMX overlaps with DUNE's kinematics

- Left figure shows nominal LDMX setup for dark matter search
- Right figure heatmap shows DUNE neutrino event distribution
- LDMX can measure cross sections below the 40◦ contour

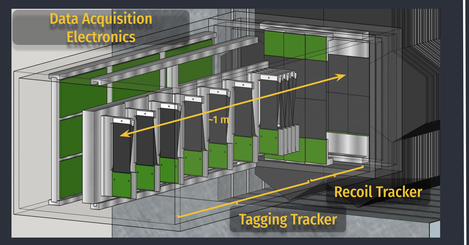


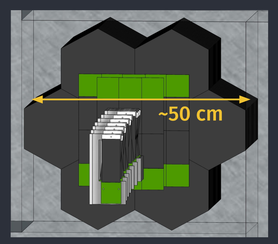


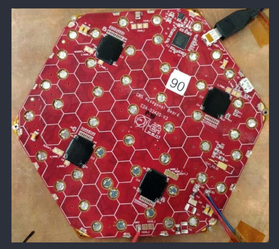
Detector concept



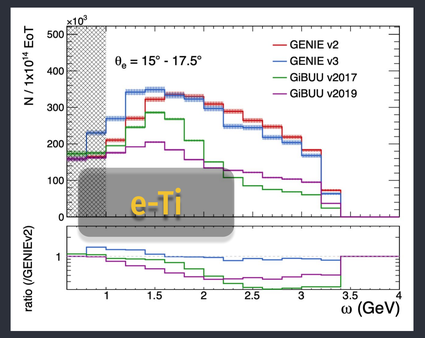
- 4 x 10^{14}, 4 GeV electrons will be delivered onto a 10% X_0 tungsten target in Phase I
- Incident e- are tagged with 7 layer silicon strip tracker, $\delta p/p \sim 1\%$
- Recoil tracks measured with silicon strip tracker, $\delta p/p \sim 5\% - 10\%$ and p_t resolution of < 10 MeV
  - Tracker acceptance out to ~40° angle down to 60 MeV
  - Good Pion/Proton separation below 1.5 GeV with dE/dX
- 40 X_0, 30 layer high granularity Si-W sampling electromagnetic calorimeter
- A scintillator-steel sampling hadronic calorimeter
  - Energy resolution for neutrons of 5% ⊕ 40%/√E/GeV







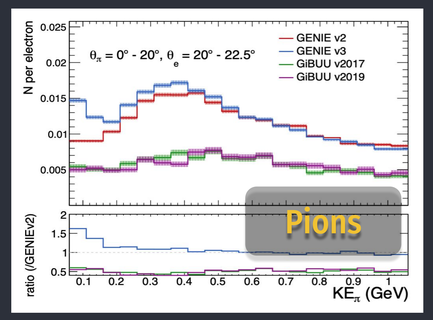
Inclusive measurements

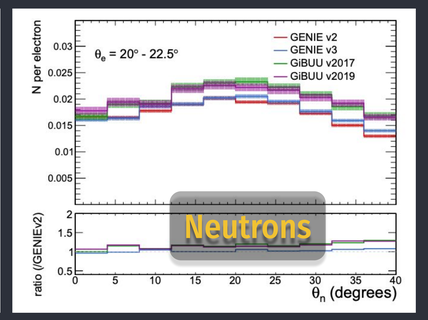


- Nominal LDMX design can measure inclusive electron-nucleus cross sections with superb resolutions
- High statistics sample were generated using different versions of GENIE and GiBUU and propagated through the nominal LDMX design
- Simulated event rates differ by a factor of 2 for different generators

(Semi) Exclusive measurements

- Crucial for neutrino energy reconstruction
- No existing data in relevant phase space





- High statistics, high efficiency, sufficient resolutions

Summary

LDMX will measure electron-nucleus cross sections extremely relevant to neutrino long-baseline oscillation program.